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CURRENT STATUS OF RESEARCH AND APPLICATION OF BIOMASS ENERGY IN THE PEOPLE'S REPUBLIC OF CHINA

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I. Executive Summary

This trip, May 1982 to June 1982, was sponsored by the office of International Cooperation and Development (OICD) of the U.S. Department of Agriculture, Washington, DC 20250. Expenses to and from China were paid by OICD while all expenses within China were paid by the Chinese Ministry of Agriculture, Animal Husbandry and Fishery.

The purpose of the trip was to study the current status of research and application of biomass energy, with emphasis on biogas digesters as developed and used in China; to study the benefits of using biogas digesters, and to determine what organizations in China are doing research and development on biogas digesters.

Both technology and economics were examined. Contacts for possible future cooperative research were made. The team consisted of Professor J.B. Liljedahl, team leader from the Agricultural Engineering Department, Purdue University, W. Lafayette, IN 47907; Associate Professor W.E. Tyner, Agricultural Economics Department, Purdue University, W. Lafayette, IN 47907; Dr. James Butler, Manager, Southern Agricultural Energy Center, U.S.D.A., Tifton, GA 31793; and Assistant Professor John Caldwell, Department of Horticulture, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060.

The arrangements in China were made by the Chinese Ministry of Agriculture, Animal Husbandry and Fishing. The travel in China consisted of about one week in and around Beijing; two weeks in Sichuan Province (Chengdu and Chongqing); one week traveling to and around Wuhan; and one week at Guangzhou.

Several useful contacts were made. All of the contacts are listed in the Appendix. The most useful contacts were with:

1. Tao Dinglai, Director
   Chinese Academy of Agricultural Engineering Research and Planning
   Agricultural Exhibition Road South
   Beijing

2. Wu Yizhe, Director
   Chengdu Institute of Biology
   The Chinese Academy of Sciences
   P.O. Box 415, Huaxi Campus
   Chengdu, Sichuan Province

3. Yu Yonglan, Head
   Soil and Fertilizer Institute
   Hubei Province Institute of Agricultural Sciences
   Wuhan, Hubei Province

4. Wu Wen, Director
   Guangzhao Institute of Energy Conversion
   Chinese Academy of Sciences
   81 Central Martyr's Road
   Guangzhou, Guangdong Province

The major research effort on biomass energy in China was on biogas digesters. About 7,000,0000 biogas digesters are in active use, we were told. Research activities consisted of: studies of the construction of digesters; studies of the effect of C/N ratio; water content; temperature; retention time; and bac-

teria. The major purpose of the biogas digesters in China was to produce energy (primarily methane), however, the Chinese were also studying the fertilizer value of the effluent and the effect of the digesters on sanitation.

We noted the following problems associated with their extensive use of biomass.

a. Severe soil erosion resulting from excessive removal of biomass from the soil, and

b. Lack of mechanization of biogas systems.

We were impressed with the studies going on within the many communes and research institutes. The data on usage appeared to be fairly complete. There appeared to be good communication between the research institutes and the communes. Many of the provinces, counties, communes and brigades had specialists whose job was to provide technical information to the many people using the digesters.

The most common use of biogas was for household cooking and lighting. The usual household digester was about 8 cubic meters in size. Much larger digesters produced biogas for drying tea, drying silk and for engine fuel. We saw one truck and several engine - generator installations using biogas. Two types of engine conversion were being used. Conventional diesel engines were modified so that up to 70 percent of the fuel was biogas and 30 percent diesel fuel. Some original diesel engines had the fuel injectors replaced with spark plugs and the compression ratio changed to about 15:1, thus making the diesel engine into a very efficient spark ignition engine.

We were also given information about the fertilizer value of the digester effluent. The sanitary value of biogas digesters was also discussed briefly.

We obtained some information on other forms of alternate energy being used in China. Some research work was being done on solar and wind energy. One small hydroelectric plant was observed. Very little research work was being conducted on ethanol production and use. We saw one research project studying the possible use of mixtures of coal powder and diesel fuel in diesel engines.

II. Observations Regarding Subject of Study in Areas Visited

In general our group was impressed with the extent of research and use of biogas digesters in China.

We believe that the technology of biogas digesters is quite advanced in China. Very likely, more advanced than in any other country.

We found the Chinese engineers, scientists, extension-type workers, commune and brigade leaders very willing to share with us their knowledge of biogas digesters.

Except for two laboratories under the Academy of Sciences, the Chinese laboratory facilities appeared to be poorly equipped. Good planning and good statistical treatment of research data appeared to be lacking. Only one small computer (Apple) was seen in all of the laboratories visited.

We believe that it would be very valuable for some U.S. scientists and engineers to spend 6 to 12 months studying and working at the two research groups under the Academy of Science (Chengdu Institute of Biology and the

Guangzhou Institute of Energy Conversion). The U.S. scientists and engineers would need to have a working knowledge of Mandarin. It would also be necessary that the individuals be willing to live and work in spartan Chinese conditions.

III. Effect of Biogas Digesters on Health and Environment

One of the advantages of biogas fermentation is that it reduces the spread of diseases and parasites associated with animal and human wastes. Four of the 13 communes visited cited improved health as one of the advantages of biogas fermentation. Two of those four gave statistics on the improvements in health that accompanied the introduction of biogas fermentation.

The Da Hau Commune (No. 6 Brigade, No. 5 Production Team), Sichuan Province, reported that before the introduction of biogas, 50% of the population suffered from hookworms. In addition, there were 9 cases of schistosomiasis (snail fever). Since the introduction of biogas in 1977, the infection rate of hookwork has dropped to 3-4% of the population, and there have been no cases of schistosomiasis.

The head of the Lei Shen Tai Brigade, Tong Hai Commune, Hubei Province, provided information regarding the whole commune. The commune consists of 33 brigades. Of these, 23 brigades have biogas digesters, while the remaining 10 do not. Since the introduction of biogas, the incidence of cases of snail fever, malaria, and diarrhea has been fewer in the 23 brigades with biogas than in the 10 without biogas.

In the Lei Shen Tai Brigade itself (one of the 23 with biogas), before 1978 there were several hundred cases of malaria among the brigade's 2,870

members, whereas after 1978 this disease has been nearly eliminated. Schistosomiasis, which was also rampant before 1978, has similarly nearly been eliminated. The incidence of diarrhea has also been reduced.

Follow-up questions on these improvements in health revealed that the introduction of biogas in this area was part of an integrated program for the control of schistosomiasis. The commune is in the lake region of the Chang Jiang (Yangtze River), between Yichang and Wuhan in southern Hubei Province. Many clinics have been set up in this area for the prevention and cure of schistosomiasis, and efforts have been made to bury the snails.

The information from this commune is an example of the lack of separation of effects of multiple changes that was also observed in the reporting of yield increases due to effluent use, improvements were initially attributed to the introduction of biogas. Additional questioning indicated, however, that biogas was part of a total package. The extension personnel evaluated biogas in the context of the overall effect of the total package rather than in terms of individual effects due to biogas.

More fundamental research on the effects of biogas fermentation on disease and parasite control has been done by the Sichuan Institute of Anti-Parasitism, Chengdu, Sichuan. This institute has investigated the time required for the sedimentation of worm ova in digester slurry liquid and the conditions necessary for the death of ova in slurry liquid and sludge. The following discussion is based on their data (1).

The specific gravities of the ova of the common parasites hookwork (1.060), roundworm (Ascaris) (1.140), and snail fever (Schistosoma) (1.200) are all greater than that of the liquid phase of the digester slurry (1.005-

1.010). In 20 hours, 95% or more of the ova of these 3 parasites either sink to the bottom or remain in the scum layer at the surface of the liquid.

With mesophilic fermentation (35-38°C), the ova of common parasites were destroyed within 23 days. With fermentation under ambient temperature conditions (10-29°C inside the digester), however, not all the ova were destroyed even after 90-100 days (Table 1).

Table 1. Days required for destruction of ova at different fermentation temperatures.

Parasite ova	Days required for ova destruction: Mesophilic fermentation (35-38°)	Ambient temperature fermentation (10-29°C): Summer	Autumn	Winter
snail fever (*Schistosoma*)	13	8-14	13-22	40
roundworm (*Ascaris*)	18	>90[z]	>90[z]	>100[y]
hookworm	23	76-87	70-90	ND
lung fluke (*Paragonimus westermanii*)	8	ND	ND	ND

[z] 73% destroyed at 90 days

[y] 53% destroyed at 100 days

ND = no data given.

Moreover, while conditions in the digesters are unfavorable for parasite ova, they do not assure immediate, complete ova destruction. For example, anaerobic conditions in digesters are effective in destroying hookwork ova in 9 days, but roundworm ova can survive up to 3 months. The ammonia content of the liquid is usually about 0.07%, but even at a 2% concentration, it takes 6 or more days to destroy the ova of snail fever, hookworm, and roundworm.

The above information indicates that in the ordinary "three-in-one" household digester which operates at ambient temperature and receives new fresh fecal material daily, there will still be living ova in the effluent. Since the national standards for effluent sanitation require that no living ova of Stistosoma or hookworm remain in the liquid effluent, the Institute of Anti-Parasitism recommends a 2-stage digester design. In this design, effluent from the middle layer of the first digester flows into the second digester for further fermentation. Effluent for fertilizer use is then taken from the middle layer of the second digester.

Since the bulk of the ova settle in the sludge, the Institute of Anti-Parasitism recommends that it be disinfected before using it as fertilizer. Three methods of disinfection are suggested:

1. High temperature (60-70°C) composting.

2. Ammonia disinfection by adding urea dissolved in water to a sludge pile.

3. Ammonia disinfection by mixing sludge, soil, and urea into granules and allowing the granules to dry.

In none of the communes visited by the team were two-stage digesters observed. The sludge is usually removed only twice a year from single-stage "three-in-one" digesters, but effluent is withdrawn regularly (for example, every 3-5 days in the Tong Hai Commune, Lei Shen Tai Brigade, Production Team No. 7). Thus, the number of parasite ova may be reduced, but the effluent from "three-in-one" digesters would not meet the national standards. This suggests that the expanded use of the "three-in-one" digester has resulted in improved but not absolute sanitation.

The above conclusion would appear to be confirmed by survey data presented by the Institute of Anti-Parasitism (1). In 3 survey examples, hookwork infection was markedly decreased through a combination of medical treatment and waste management (by building digesters). In none of the 3 cases, however, was infection entirely eliminated.

In the case involving the largest number of production teams, 57, the hookwork infection rate was reduced to 23.5% of the population of 12,000 in winter 1975, by medical treatment. After spring 1976, no further medical treatment was given, but wastes were disposed of in digesters. In fall 1978, the hookworm infection rate was again measured and found to be 22.4%.

In the other 2 cases involving 5 and 3 production teams, respectively, hookworm infection rates were reduced from 55-64% to 4-5%, through a combination of medical treatment and waste disposal in digesters. In 2 teams where digesters were either not built or not used for waste disposal, infection rates increased in spring 1979 to up to 3 times the 5% rate of fall 1978. The latter rate had been reached after 5 years of medical treatment of the population.

In addition to control of parasites contained in excreta, the disposal of excreta in biogas digesters also is effective in reducing diseases spread by flies. The data provided by the Institute of Anti-Partasitism indicated a two-thirds reduction in enteritis and bacillary disentery in one county following the introduction of biogas. As in the examples from the communes cited earlier, however, the decrease in this case was due not simply to the building of biogas digesters, but to an integrated effort which included "other sanitary measures".

Waste disposal in biogas digesters also can reduce environmental pollution. In the Dang Yang County Slaughterhouse, Hubei Province, swine excreta and raw slaughterhouse wastes were formerly disposed of in 20 _mu_ of paddy and ponds surrounding the slaughterhouse. As a result, not only were the ponds made useless, but also the odor and breeding of flies and mosquitos in the polluted water caused considerable local resentment. After the introduction of waste disposal in biogas digesters, digester effluent is now fed into the ponds. The effluent does not cause odor and insect problems. In addition, it serves as food for fish.

Several of the communes visited also pointed out one other advantage for families using biogas: smokeless cooking. Prior to the introduction of biogas cooking, cooking was done with wood, coal, and/or stalks, all of which produce considerable smoke. The smoke was uncomfortable for the person cooking, dirtied kitchen walls, and yellowed clothes. Now, with clean biogas cooking, all of these environmental problems are eliminated.

IV. Observations on Microbiology of Biogas Fermentation

Among the 7 research institutes and 2 universities visited by the team, only the Chengdu Institute of Biology and the Guangzhou Institute of Energy reported fundamental research on the microbiology of biogas fermentation. Both institutes are under the Chinese Academy of Sciences (Academia Sinica). The work at Guangzhou was done in cooperation with the Chengdu Institute of Biology. The latter institute provided the team with a bulletin (2) and an article (3) on their research, and clearly appeared to be the lead institute for this work.

Biogas fermentation has traditionally been divided into 2 stages, an initial acid-forming stage followed by a methane-producing stage. A recently published book on biogas production and utilization (4) follows this traditional division of stages and shows pyruvate, acetate, and other low molecular-weight organic acids as substrates for methane bacteria. On the other hand, Shuler (5) cites research which suggests that the methane-producing bacteria are unable to utilize organic acids other than formate and acetate. Shuler, therefore, adds a third stage between the 2stages of the traditional sequence, that of the H_2-producing acetogenic bacteria. These bacteria break down the low-weight organic acids produced in the first stage into acetage, CO_2, and H_2, which are then used by the methane-producing bacteria.

In light of the above discussion, it is significant that the Chengdu Institute of Biology has focused on the identification of H_{2y}-producing bacteria in their research since 1976. All together, they have identified 24 strains of H_2-producing bacteria out of 51 strains isolated from an enrichment

culture. The breakdown of strains is shown in Table 2 (3).

Table 2. Types of H_2-producing bacteria.

Family	Genus and species	Strains	
		Number	Percent
Enterbacteriaceae	Enterbacter cloacae	14	58
	Escherichia coli	1	4
	Citrobacter freundii	1	4
	Hafnia alvei	1	4
	Serratia marcescens	4	17
Bacillaceae	Clostridium acetobutylicum	3	13
Total		24	100

There were considerable differences in H_2 production among the 24 strains, ranging from 3 strains which produced only a trace of H_2 to the most active strain which produced an average of 413 ml/day (2).

When 3000 ml of a culture of H_2-producing were added to 3000 ml of sludge from the Chengdu waste water treatment plant and the resulting mixed culture fermented at 30°C for 1 month, during days 9-16, the CO_2 content of the mixed culture dropped to 0%, while the CH_4 content exceeded 90%. Total methane yield after 19 days was 11.9 (1). In contrast, the CO_2 content of the control sludge ranged between 24-34% and the CO_2 content between 59-66% during the days 9-16, and total methane yield after 19 days was 9.0 [1]. These data suggest that enrichment of sludge with H_2-producing bacteria increased the supply

of H_2 needed by the methane-producing bacteria for the additional reduction of CO_2 to CH_4 (2,3).

The Chengdu Institute of Biology is also conducting research on identification of the methane-producing bacteria. Since 1970, they have isolated 3 strains of Methanobacterium with short reproductive generation times. One strain, belonging to M. thermoautotrophicum, has a reproductive generation time of less than 3 hours, in contrast to the 4-6 hours of most methane-producing bacteria (1).

V. Suggestions and Recommendations

1. Regarding Subject of Study, which was primarily biogas,

    a. There is more to be learned from China by scientists, engineers and economists.

    b. The large livestock farmers in the U.S have an opportunity to save valuable petroleum energy at a possible economic saving by using a large biogas digester.

    c. Small household digesters as commonly used in China would not likely be accepted in the U.S.

2. Regarding future visits we believe in-depth studies should be made by biogas researchers from the U.S. Six to 12 month studies at the two Academy of Sciences Institutes visited would be ideal. Similar visits to the U.S. by Chinese researchers should be encouraged.

3. Cooperative research sponsored by the USDA or DOE should be encouraged in connection with future visits by Chinese visiting the U.S. and U.S. scientists going to China.

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